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THE MEASUREMENT OF ELECTRICAL CONDUCTIVITY IN THE STRATOSPHERE

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Final Report

P. Roger Williamson

March 6, 1978

U.S. Army Research Office

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The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

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Measurements of the galactic cosmic ray ionization rate in the stratosphere have been used to develop a global model. Above 25 km an analytic form for the height dependence of ionization was found. In the second part of this work, ion conductivity was measured near the sampling aperature of a balloon-borne ion mass spectrometer. Data from two flights demonstrated that ionization was present near the aperature at all times during both flights but that a large variation could sometimes occur in the probe current. On the second flight a turbulence layer was observed near 80,000 ft. altitude.

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Problems

The problems studied under this grant were divided into two main parts both related to the measurement of electrical conductivity in the stratosphere as described in our original proposal. The ARO has supported work at the University of Denver in the development and flight of a balloon-borne ion mass spectrometer. The sampling of ions in the stratosphere is a difficult problem with very little known about the processes which are important in sampling ions in situ from a balloon-borne platform. We discussed these problems in our proposal and in an in-house technical report while at the University of Denver. The in situ sampling problem which we studied in this grant was related to the presence of ionization at the sampling aperature of the ion mass spectrometer. The sampling duty cycle of the ion mass spectrometer is very low and some means is needed to establish the nature of the ionization which is being sampled in view of the widely varying and unknown character of the ionization at the sampling aperature.

The ion mass spectrometer measurements of the ion composition in the stratosphere will, of course, be compared to the ion chemistry model. The total ion density depends upon the ionization rate, Q, which must be included in the model and should be measured during flight operations. Although Q can be measured with an ionization chamber during flight and the measured value used in the model calculations for comparison of the ion model to flight data, it is desirable to be able to predict the Q value before a flight and also to provide an alternative means of determining Q if the ion chamber should fail as did in fact happen on several flights. Additionally, we have known for some time that an ordering of

the stratosphere ionization measurements appeared possible and might provide a global model at all altitudes which would be of interest not only in support of in situ ion measurements but as an input to ion chemistry modeling and as a means of calculating the global production rate for NO as a result of the ionization of N_2 (Nicolet, 1975).

Results

Significant results were obtained in both portions of this study with the problems stated above satisfactorily resolved.

A conductivity probe, which measures the conductivity of air and is sensitive to turbulence as well as ion density and mobility, was constructed and integrated into the DU/BRL ion mass spectrometer. Ions were observed during the last two balloon flights and the conductivity probe worked well throughout both missions.

The first flight was designated as engineering development and a relatively short load line was used so that the payload was close to the balloon. We expected that air motion at the position of the ion mass spectrometer entrance aperature would be relatively small since wind shear would not contribute a large relative wind component as a result of the short distance between the balloon and the gondola. Indeed, the conductivity probe data demonstrated that (1) ions were present near the ion mass spectrometer entrance aperature throughout the flight with only moderate variations in the conductivity observed, and (2) turbulence and relative wind were small or negligible throughout the flight. During some portions of the flight the ion conductivity probe current varied by only a few percent at most for several minutes indicating an ideal

sampling environment with no perturbing effects from turbulence or other possible sources. At other times the conductivity probe current was observed to decrease by as much as 50% with relatively sudden excursions which were not always correlated with sampling operations.

The next and last flight was made with a long load line. The gondola was several hundred meters below the balloon so that the air mass near the ion mass spectrometer was undisturbed by the presence of the balloon. In addition, a large relative wind was expected at the gondola position as compared to the previous flight, since the balloon moves in an air mass substantially removed from the gondola. The conductivity probe current measurements were not entirely as expected but not really too surprising. In contrast to the previous flight with a short load line, in this flight the conductivity probe current never indicated a steady, undisturbed period. The current was steadily varying throughout the flight even during the descent phase where the horizontal component of the relative wind might have been thought to be relatively unimportant.

The exact mechanism which produced these current variations is not known. Relative air motion or real conductivity variations could produce these changes. In addition, the importance of relative air motion to the problem of sampling through an orifice is not known. However, we have established that the nature of the air mass at the sampling entrance aperature was substantially disturbed throughout the mission in which a long load line was utilized.

Another interesting result of the second flight was the observation of a turbulence layer at 80,000 feet during the valved descent before

termination of the flight. For a few minutes as the balloon-borne payload passed through the turbulence layer, the character of the conductivity probe current changed and exhibited relatively rapid variations as compared to previous portions of the flight and to the data obtained below this layer. Here again the conductivity probe, which operated continuously throughout the flight supplying real time data, indicated the nature of the air mass being sampled by the ion mass spectrometer.

Publications and Technical Reports

A paper entitled "An analytic model for the galactic cosmic ray ionization rate above 25 km" was presented at the AGU meeting in Washington, D.C. on April 15, 1976. Material contained in this paper formed the basis for the more extensive model which we have developed and this work will be submitted to the Journal of Geophysical Research Blue Section.

The conductivity probe study will be reported in the Journal of Geophysical Research Green Section and will discuss the observational differences between the two balloon flights.

Scientific Personnel

Dr. Williamson was the only scientific person supported under this grant.

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